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(54) **Communications arrangement and method**

(57) A route through a multi-node network is selected on the basis of a (weighted) combination of at least two performance parameters evaluated for each of a plurality of possible routes. As described two possible lines are judged by fuzzy logic with regard to their performance, their time response and their safety. Two intermediate variables result from this, which intermediate variables are processed by means of a main regulating set to form a weighting factor for the respective line. This weighting factor is further used by a routing method, which is to establish the shortest path for a communications connection, in order to establish the appropriate connection. This invention is realised in a particularly favourable manner in a multi-node network.

FIG 2

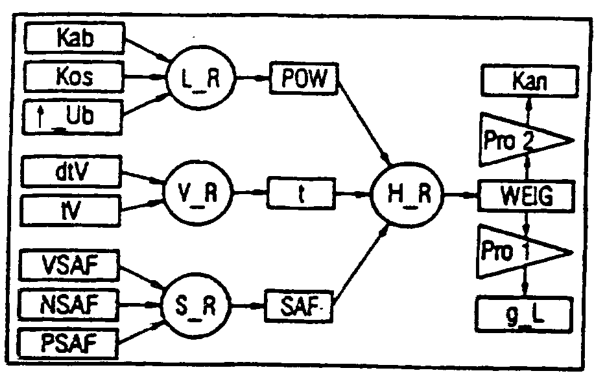

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FIG 1

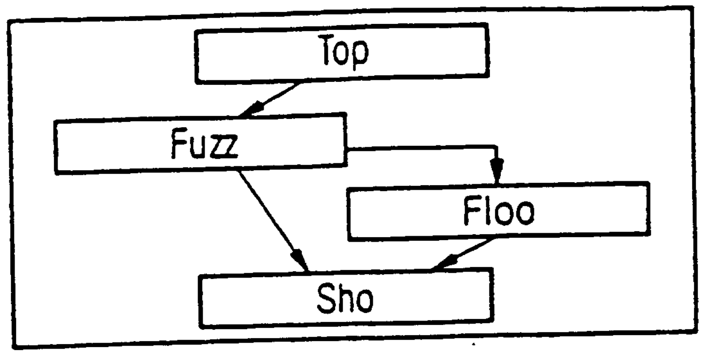


FIG 2

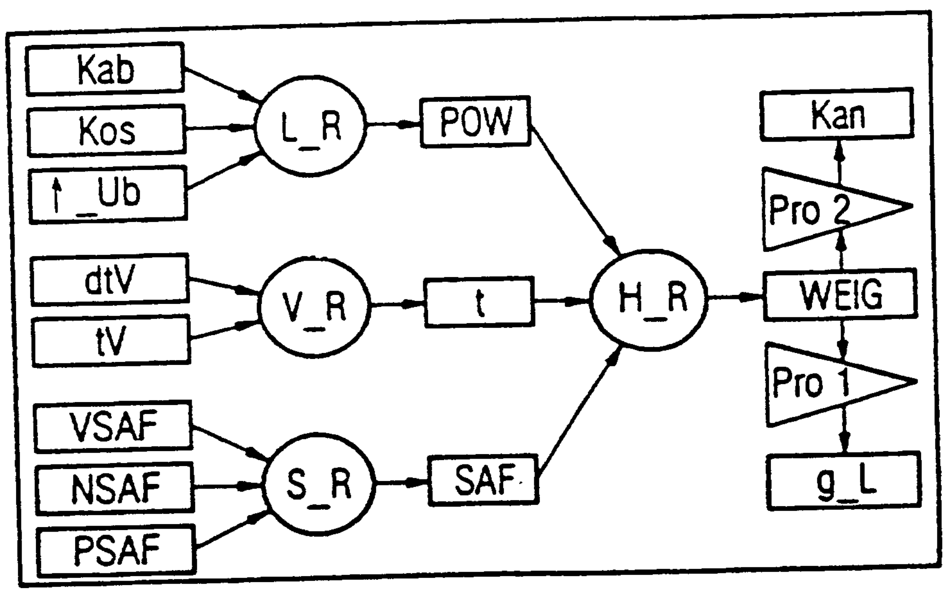


FIG 6

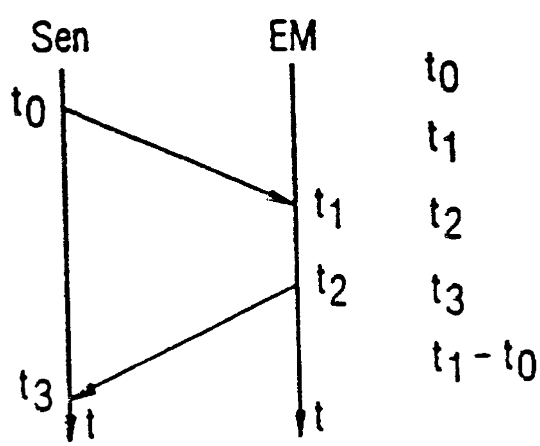


FIG 3

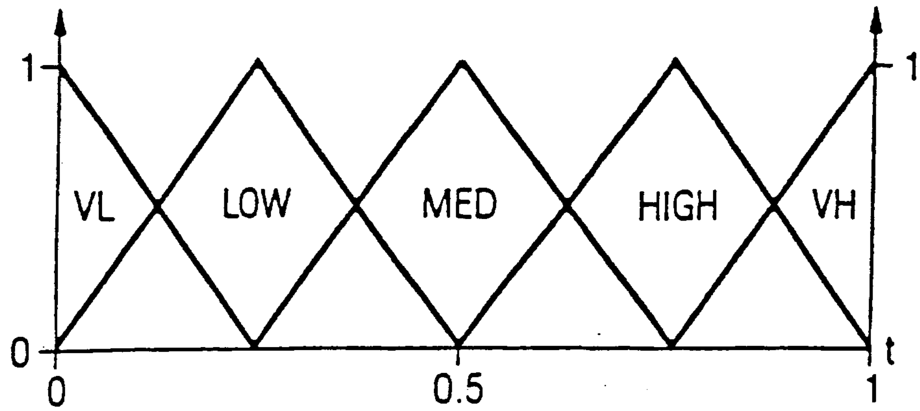


FIG 4

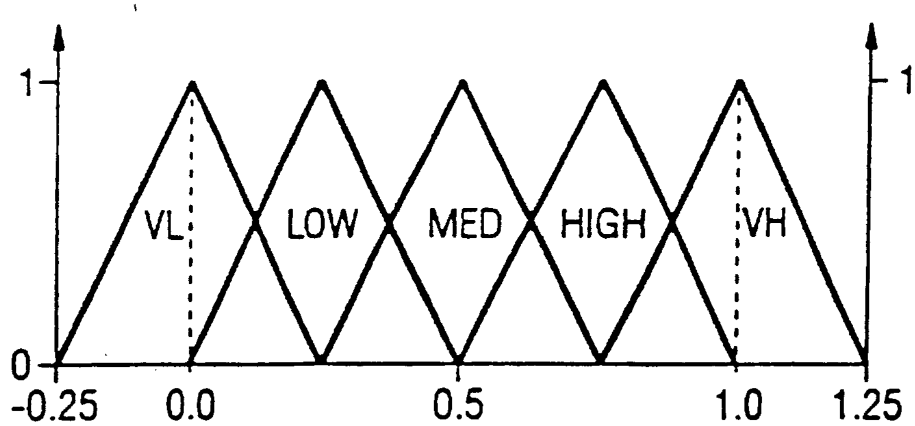
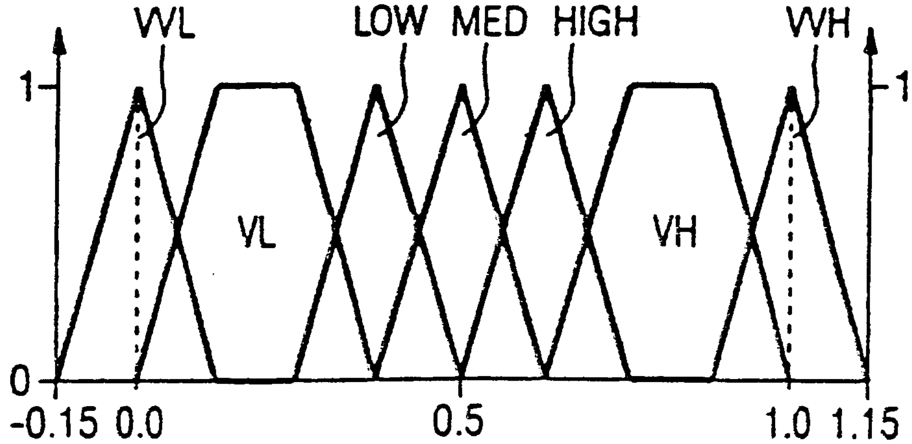


FIG 5



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COMMUNICATIONS ARRANGEMENT AND METHOD

The expansion of the communications networks which are available is advancing rapidly on a world-wide scale. The internet is here mentioned by way of example. In such communications networks, communication partners can be connected by way of different relay stations on various communications paths. Such communications networks are highly complex systems which contain, for example, several thousand components. The routing function of the network is therefore given great significance, which function selects each connection of one component to the other components in the network, by way of which connection a message is to be transported. In the ISO-OSI reference model for communications networks, the selection of the best communications connection between a sending node and a destination node is one of the main functions of the third layer. The problem for a communication subscriber to find the best possible connection occurs in each network which does not allow a sender to be connected directly to a receiver by means of a single transmission connection, but where instead of this several intermediate communications paths have to be linked. The routing problem in networks therefore presents an archetypal combinatorial optimisation problem for such multi-node networks.

If different communications paths are possible between two communication partners when setting up a communications network over several relay stations, routing must be considered. In order not to load the network unnecessarily, it is desirable to achieve the shortest possible paths between two partners. Such routing strategies of the shortest path are based, for example, on information about the network topology. For example, in accordance with a dimension, a length or a weight is allocated to the observed network seen

in terms of graph theory for each connection in the network. With an algorithm which finds the shortest path, the communications path from a given source node to each other node of the network can be calculated.

In order to be able to effect the exchange of data packets using such a method, a path or a set of paths from which the routing-algorithm can select has to be established in the network between a receiver and a sender before the transmission. For example, routing tables are stored in each communication node, which tables indicate the correct output to an intermediate communications link for a communication packet which is being received.

In order to prepare correct routing tables in the individual communication nodes along a communications path, there are various routing strategies. One of the most simple strategies for finding a path involves specifying a fixed routing. In this connection, the communications connection is inflexible and the communications connection is always maintained by way of the same intermediate communications links.

A further strategy involves broadcasting each data packet to all other network nodes. This way of proceeding can be necessary if topological alterations occur in the network, for example. Such topological alterations can be errors or alterations for example, and in this case broadcasting is used to inform all communication subscribers of the alterations. A variant of broadcasting is flooding through the network. In this connection, the source node sends data packets to all of its adjacent nodes and these in turn send data packets to their further adjacent nodes, apart from those which sent them the message.

The opposite of fixed routing is adaptive routing. This means that the network or the communications connection can react flexibly to dynamic alterations in

the network, which alterations relate to the topology or the load of the network. In this connection, a local routing strategy uses locally accessible items of information, such as, for example, the lengths of the queues of all outgoing connections. Methods which use these strategies are also termed isolated routing algorithms. Distributed routing strategies, which represent mixtures of global and local routing strategies, are also known. Of the known methods, however, all require items of information about the network topology, the load on the network and the cost of the communications connections. If, for example, a centralised routing is used, the status of each individual communication node in the network is monitored by a routing-control-centre, such as, for example, a list of neighbours, actual lengths of the queues, topology present at the time, the traffic data for the individual line connections since the last report, etc. New routing tables can be prepared by this central routing-control-centre and distributed to all further stations.

A further possibility of routing strategies is multi-path routing. In this case, if more than one optimal communications path is possible, the communication load can be distributed over the possible paths. For example, it is also possible to weight the possible path with probabilities for the occurrence of different loads. By multi-path routing, for example, the delay when distributing data packets through the network is minimised. The criteria for finding the optimal path through the network are also termed routing-metrics.

A further possibility is distributed adaptive routing. In this connection, each node in the network must carry out the following activities, for example:

- collecting and measuring items of information

about the network topology because, depending on the network, there are many criteria which can influence the routing decision;

- exchanging the collected information with other communication nodes; this is generally effected by flooding in the network;
- calculating the shortest path to all other nodes, based on the topology information, something which represents a well-solved known problem.

However, all known routing strategies which determine the shortest path have in common the fact that they use only one network parameter in order to generate the routing information. In this case, different routing methods use different parameters, such as, for example, the transmission delay, the number of relay stations, etc. The routing decision is, however, prepared exclusively with the aid of this parameter, so that the network communication is optimised only with the aid of this single parameter, such as the delay time for example; further important criteria for a network user, such as the connection cost for example, are not considered.

The invention therefore seeks to provide an improved communications arrangement and an improved method for evaluating at least two multi-part communications connections between two communication partners in a multi-node network.

According to one aspect of the invention, there is provided a method for selecting a communications connection between two nodes of a multinode network from a plurality of possible such communication connections, comprising the steps of:

for each communication connection evaluating at least two parameters which are a measure of the performance of the communications connection; and

selecting a communications connection from the plurality of such connections on the basis of the weighted combination of the at least two parameters of said plurality of connections.

According to a further aspect of the invention, there is provided a method for evaluating at least two multi-part communications connections in a multi-node network, having the following features:

a) at least two evaluation categories for evaluating a communications connection are predetermined;

b) for a respective communications connection, at least one respective measured value is detected to form each predetermined evaluation category, which measured value describes the connection with regard to the respective evaluation category;

c) for the respective communications connection, an evaluation measure is determined by evaluating the associated measured values, at least with regard to the fulfilment of the respective evaluation category, in the form of degrees of fulfilment and all degrees of fulfilment are linked to each other in such a way that the communications connection which has higher degrees of fulfilment with regard to the evaluation categories receives an optimal evaluation measure.

According to a yet further aspect of the invention, there is provided a communications arrangement for implementing the method according to one of the preceding claims, in which arrangement the communication nodes and partial communication sections between the communication nodes are arranged in such a way that two communication subscribers can be connected to each other by way of at least two communications connections.

Further developments of the invention emerge from the dependent claims.

A particular advantage of the method in accordance with the invention consists in that consequently for the first time several metric parameters, which describe different aspects of the communications connection, can be referred to when evaluating the connection. In a particularly advantageous manner, when using the method in accordance with the invention, the evaluation categories of time response, safety and performance of the communications connection are selected, because in this way a comprehensive description and evaluation of the respective connection is possible.

Advantageously, when establishing the measured parameters, i.e. the routing metrics for the individual evaluation categories, several measured variables are detected, because in this way a reliable statement can be made about the respective state of the network. In this way it is also possible to weight the individual measured variables and to weigh them against each other.

In a particularly advantageous manner, the method in accordance with the invention is carried out by the use of fuzzy logic, because this is known for the fact that it permits in a particularly simple manner the use and the evaluation of several equivalent measured variables. In this connection, a single fuzzy regulating set is advantageously evaluated for each individual evaluation category.

In a particularly advantageous manner, several measured variables, which are evaluated in a first step by means of a single fuzzy regulating set, are again represented as a linguistic variable by the method in accordance with the invention, in which case in this way there can be found for each individual evaluation category a linguistic variable, which in connection with a further fuzzy regulating set, the main

regulating set, contributes to a weight for the respective communications connection to be evaluated.

Advantageously, in order to be able to effect a practical judgement of the connection, fuzzy regulating sets are formed for cost and transmission capacity, transmission time and cost, delay time and alteration of the delay time, as well as for the connection safety and the packet safety.

Advantageously, with the method in accordance with the invention, in a second evaluation step, fuzzy rules are evaluated for the main regulating set, which rules connect the time response of the communications connection to the safety, the time response of the communications connection to the performance and the performance of the communications connection to the connection safety. By using these combinations, a practical evaluation of the respective connection is guaranteed.

Advantageously, the method in accordance with the invention for evaluating potentially possible communications connections is used and selects the communications connection which receives the most favourable evaluation measure, for example the weight. In this way it is ensured that an optimal advantage is achieved for a communication user.

Advantageously, the method in accordance with the invention is used in a communications arrangement which permits ring-shaped connections of two communication subscribers by way of several relay stations, because in this way the network load and the cost for the communication subscribers can be minimised.

Advantageously, the method in accordance with the invention is carried out on each node of a communications network, because in this way a redundancy is ensured and the correct network data are always currently available.

For a better understanding of the present invention, and to show how it may be brought into effect, reference will now be made, by way of example, to the accompanying drawings, in which:

Figure 1 shows a block diagram as an example of a method in accordance with the invention;

Figure 2 shows a diagrammatic representation of a fuzzy evaluation system;

Figure 3 shows an example of the association functions for the linguistic variable Capacity;

Figure 4 shows an example of the association functions for the linguistic variable Performance;

Figure 5 shows an example of the linguistic variable Weight;

Figure 6 shows an example of the measurement of the delay time between two communication nodes.

Figure 1 shows by way of example a diagrammatic picture for the combined action of several components in a multi-node network. For example, in one module Top of each node, the topology of the network is established. This occurs, for example, by measuring the individual connection lengths between the various nodes. For example, the delay time of each node can also be established with the connections which are incidental thereto. For example, these items of data, in connection with the help of a flooding method Floo, are communicated to all other nodes. In a further module, the best nodes are established with the aid of a theoretical algorithm, Sho. The method in accordance with the invention therefore starts where it is necessary to improve the measurement, the establishment and evaluation of the topology parameters. Further above, mention was also made in this connection of the routing metrics. For example, substantially more than only one or two parameters can easily be linked by a fuzzy system Fuzz to provide a general evaluation of

the connections. This evaluation of the connection can then be used as the input variable for a shortest-path-algorithm. Here in Figure 1, this is termed Sho. For example, a routing method of this type is to be installed in each network node. For example, each node establishes the input parameter of the connections which are incidental to it for the fuzzy system in accordance with the invention. It should be noted that in order to carry out the invention, the fuzzy logic appears to be most suitable, but that other methods can be used, with which methods several variables can be evaluated in terms of their weights. Here, only the fuzzy logic is represented, as an exemplary approach, in order to illustrate what the invention entails. For example, the method in accordance with the invention is implemented as soon as a significant alteration of one of the input parameters has occurred. This alteration is established, for example, in the module Top of the diagrammatic drawing in Figure 1 and is subsequently passed on to the evaluation module Fuzz. If this evaluation of the new connection parameters leads, for example, to an alteration of the evaluation of at least one of the connections, then, for example,

- the vector of the updated evaluations for the connections is distributed over the network by flooding,

- with the aid of a shortest path algorithm, for example the SPF-algorithm, the routing table is updated.

In the following, some input parameters for evaluating connections are specified, which parameters were not all realised in the method in accordance with the invention, however. For example, as input variables of the method in accordance with the invention, firstly all items of information available on the plane of the routing in the network are

available for selection. In particular, the following parameters seem suitable in this connection:

- the connection length as physical distance between two nodes. Furthermore, since not only the distance between two nodes, but also the nature of the transmission medium (e.g. copper cable, glass-fibre cable, radio connection) has an influence on the time which the signals require in order to get from one node to the next, it appears to be favourable to select the transmission time for a packet as an input for the method in accordance with the invention;

- if, for example, a datagram-oriented network is taken as the starting point, the transmission time for a whole packet can likewise be used, such as the signal transit time between two nodes. In this connection, "transmission time" therefore means the time which elapses from the beginning of the transmission to the medium (the first bit of the packet is fed into the network) until the last bit of the packet has reached the next node. As long as a connection exists, the transmission time is a constant variable for the respective connection;

- a further input variable which can be measured as time is the delay time which a packet experiences on its way from one node to the next. For example, in this connection, the time which passes from the instant of sending a packet to an adjacent node until the arrival of the acknowledgement which the adjacent node sends back is measured. In this connection, a time stamp having the output time is sent with the packet, which time stamp is returned to the sending node in the acknowledgement. As a result of this, a situation is achieved in which only the clock of the sending node is involved in the measurement. The constant portion of the sending time is in this connection, for example, the transmission time. In this connection, the time

which passes during protocol processing and in the queue is used. Here, for example, the load situation also enters indirectly into the evaluations of the connection, as shown in Figure 6. There, the difference between the delay time and the transmission time is represented. In Figure 6, t_0 means the instant at which the sender Sen sends off a packet. t_1 indicates the instant at which a sent packet is placed in the input queue at the receiver Em. t_2 indicates the instant at which the acknowledgement is sent back. t_3 indicates the instant at which the receiver receives the acknowledgement and can carry out a comparison of the time stamp with the internal clock. The transmission time in Figure 6 is therefore calculated to $t_1 - t_0$. The sender Sen and the receiver Em are therefore, for example, two nodes within a multi-node communications network;

- because the delay time is one of the most important parameters, the alteration of the delay time is also measured and selected as an input into the evaluation system in accordance with the invention. The ulterior motive in this case is that in the case of a temporarily increasing delay time, a connection with the next seconds having an increased time is to be expected, and this connection is therefore to be evaluated less highly;

- because the workload of a computer network fluctuates with the time of day for example, it appears sensible to likewise allow this to enter into the evaluation of a connection. If, however, short intervals are chosen for measuring the measured parameters, then fluctuations which depend on the time of day will also be detected, and it is not necessary to detect the time-of-day parameter;

- with regard to future technologies, such as ATM-networks, for example, and uses such as multimedia and

wideband services, the type of the traffic (data, language, video ...) could also enter into the routing decision. This means, however, that an individual routing table is to be calculated for each type of traffic, something which means greater expenditure on storage and computers;

- furthermore, the capacity of the line can also be taken into account, because in the case of a high delay time which is still rising, it is to be expected that the bandwidth of the connection is already completely used up;

- the message length, for example the number of packets which belong to a message, can likewise be evaluated if the said message length is known at the start of a transmission. This could be used, for example, to make predictions about the load situation which is to be expected;

- the Hop-number, previously also termed the number of the relay stations on a connecting section, could likewise be drawn into the routing decision, but is, however, only meaningful if no distributed routing takes place;

- furthermore, the age of the routing information can be used as an input for the evaluation system;

- if, for example, the cost of using a connection is drawn into the evaluation of the connection, the traffic can be routed via connections which are more favourable in terms of cost rather than via more expensive connections. In this connection, however, it should be considered that the cheap connections could be overloaded;

- a further parameter is the safety of the connection. In this connection, for example, the fault tolerance or the confidence in the availability of a connection is established as a probability that the connection does not fail;

- likewise, the fault tolerance of the adjacent node in a communications network can be made known to the respective communications network. In the case of routing decisions, for example, adjacent nodes which are known to be more stable than others can be selected;

- a further parameter can be the packet loss probability. This parameter describes the probability of a packet getting lost because of overload situations.

Advantageously, in the case of the method in accordance with the invention, these parameters which are specified can be grouped together in three evaluation categories. They serve the method in accordance with the invention, for example, as input variables for a two-step fuzzy system which establishes a weighted connection length. Advantageously, the following three groups are formed:

1) "Capacity", "Cost" and "Transmission time" are, for example, grouped together to form the group of performance criteria;

2) "Delay time" and the "Alteration of the delay time" are, for example, grouped together as criteria of the time response of the connection;

3) the three variables "Safety of the connection", "Fault tolerance of the adjacent node" and "Packet loss probability" are, for example, grouped together to form the group of safety criteria. In this connection, the method in accordance with the invention is designed in such a way that no special existing computer network needs to form the basis of its manner of operation.

Figure 2 shows an example of an evaluation system of communications connections, in accordance with the invention. It is here represented in a diagrammatic manner. In this case, rectangular boxes indicate linguistic variables, circles indicate the control base

and triangles indicate so-called processor units, which can carry out computing work. Advantageously, the method in accordance with the invention is designed as a two-step system. In the first step, for example, the input variables are divided into the three above-mentioned groups. Capacity is designated with Kap, cost with Kos, the transmission time with t_Ub. The alteration of the delay time is designated with dtV and the delay itself with tV. In the safety criteria, the connection safety is designated as VSAF, the node safety is designated with NSAF and the packet safety is designated with PSAF. For these three groups, three control bases are preferably subsequently prepared, which control bases determine the corresponding intermediate variables, i.e. the linguistic variables for performance of the connection, time response of the connection and safety of the connection. In a two-step method, these linguistic variables represent intermediate variables. It is, however, also possible that these variables are evaluated directly by way of arithmetical methods in order to determine a weight for the corresponding line. In this connection, the individual fuzzy regulating sets are designated as follows: the performance rules with L_R; the time rules with V_R and the safety rules with S_R. The intermediate variables which result for the performance are designated with POW, those for the time are designated with t and those for the safety are designated with SAF. These linguistic intermediate variables are then, for example, supplied to a second step of the main rules H_R, by which the weight for the respective line is calculated by means of fuzzy logic. For example, this weight represents an evaluation number from the interval [0, 1]. A number close to 1 in this case means, for example, a very good evaluation, and a number close to 0 analogously means a

very poor evaluation. This weight can be used directly as an input for an algorithm Sho, which with the aid of the weight WEIG calculates the best connection.

This weight is made available by way of the processor PRO1, for example, at an output of the evaluation system as g_L. At a further output, the edge weight for the respective connection in the form of the inverse weight is made available as Kan by the processor PRO2. In this connection, the two-step version of the method in accordance with the invention has the following advantages:

1. The intermediate variables can, for example, be supplied directly as input variables to a routing algorithm which functions on the basis of fuzzy rules;

2. As a result of this, the design of the control base is shaped in a manner such that it is more straightforward. It is easily imaginable that a control base for eight input variables can be very undefined. Grouping the input variables means that in this connection the design of the control base can be shaped in a more systematic way.

Figures 3 to 5 shown examples of the individual linguistic variables. For example, the interval [0, 1] as universe of discourse has been used as the basis of all of the variables. The measured values are, for example, scaled to this interval before being input into the fuzzy system. An exception to this is only the variable "Alteration of the delay time"

Figure 3 shows an example of the association function of the linguistic variables Capacity. Preferably, for the judgement of the capacity 5 fuzzy sets: "VL" very LOW, "LOW", "MED" (medium), "HIGH" and "VH" (very high) having, for example, triangular association functions at LOW, MED and HIGH or half triangular functions at VL and VH are used. Figure 3 here shows by way of example the graphic representation

of the variables "Capacity". The variable "Cost of the connection" is preferably shaped in the same way as the variable "Capacity" and likewise the variable "Transmission time of the connection". The interval [-1;1] as universe of discourse preferably forms the basis of the variable "Alteration of the delay time". Advantageously, the sign of the alteration of the delay time can then also be taken into account during the evaluation. For this purpose, the fuzzy sets are correspondingly labelled with "NM" negative-medium, "N" negative, "ZERO", "P" positive and "PM" positive-medium. The following variables which are further taken into account are preferably set up in the same way as the linguistic variable Capacity:

- delay time
- connection safety
- node safety
- packet safety

The association functions for the linguistic variables, which functions are presented here, are only examples. The specialist who wants to reconstruct the invention can also individually provide other association functions for technical reasons, which functions are not triangular but have any other curve shape. In the individual case, it can also be sensible for technical reasons to provide several fuzzy sets for the evaluation.

Figures 4 gives an example of the association function of the linguistic variables "Performance". In this connection, it should be noted that the performance was calculated by evaluating the input variables with the aid of the performance rules. For example, the variable Performance, like the input variables, consists of five fuzzy sets. It preferably represents the price-performance ratio of the connection. In order that after the defuzzification

with, for example, the 'max-dot-centroid' method, the edge values zero or 1 are also reached, triangular functions as association functions are selected for all fuzzy sets. Here, as universe of discourse, for example, the interval [-0.25, 1.25] forms the basis. The variable "Time" is, for example, set up in the same way as the variable "Performance". It represents the requirements with respect to time of the connection which is considered. In this connection, the set VL represents a very poor time response, i.e. a high delay time. Analogously, the other fuzzy sets of the variables "Time" represent correspondingly favourable time relationships. The variable "Safety" is thereby preferably set up in the same way as the variable "Time". It should again be pointed out that these variables which are mentioned are intermediate variables which have already emerged from a fuzzy-logical evaluation of the input variables. These intermediate variables are preferably established in order to be able to shape more easily the individual regulating sets for the evaluation of the variables. Here, the fact that only three input variables are to be evaluated by the main fuzzy regulating set H_R while eight input variables have to be linked to each other by means of fuzzy rules when evaluating all of the input variables is preferably exploited.

Figure 5 shows an example of the association functions of the output variable Weight. This preferably consists of seven fuzzy sets "VVL", "VL", ..., "VH", "VVH". These are, for example, distributed over the interval [-0.15, 1.15]. Here, for example, triangular or trapezoid association functions are provided as association functions for VL and VH. As a result of this, edge values are allotted a higher significance. This has the advantage that the final decision of the fuzzy evaluation system will achieve a

more exact result for a very good or very poor evaluation, while in the middle region a finely stepped result is achieved.

As already mentioned above, control bases have to be provided in order to evaluate the linguistic variables. Here there are four control bases, for example, because of the two-step way of proceeding. The rules which are laid down in the four control bases in this case represent an important component of the method in accordance with the invention in addition to the linguistic variables. They link the fuzzified input variables to the intermediate variables or to the final connection weight. There now follows an overview of the individual control bases as an example of the corresponding evaluation of the variables. The formulation of the rules is a heuristic and subjective process particularly in the field of computer networks, because depending on the target idea of the designer, the rules can appear completely different. The result of this is that a specialist can provide in the individual case different fuzzy evaluation rules as a function of the system which is to be controlled or the networks which are to be evaluated. In this connection he can, for example, in particular link different variables, or even provide more or fewer fuzzy regulating sets in accordance with his requirements. The rules for linking the performance parameters of the connection are contained in the control base for the performance rules L_R in Figure 2. In this connection, the variable "Performance" represents the price-performance ratio of a connection. Thus, for example, a connection having low costs but in this connection high capacity and low transmission time is evaluated as being very good, while a connection having the same performance data but a high cost is seen as good but not, however, as very good. The control base L_R

preferably essentially consists of two groups of 25 rules each. In the first group, for example, the variables Capacity in the matrix Kap and Cost Kos are linked by means of logical AND-operation. This is shown in Table 1. This operation is symbolised by an arrow and by the term AND. From this control base, 25 rules can therefore be derived by AND-operation of the individual factors. This is shown in Table 1.

Table 1

AND ↘

Kos / Kap	VL	LOW	MED	HIGH	VH
VL	MED	LOW	VL	VL	VL
LOW	HIGH	MED	LOW	LOW	VL
MED	VH	HIGH	MED	LOW	VL
HIGH	VH	HIGH	HIGH	MED	LOW
VH	VH	VH	VH	HIGH	MED

In the first column, or second line, are the terms which are linked in the premisses with the aid of the AND-operator. At the point of intersection of the line and the column of the premiss terms are the terms of the output terms. In the second group, the variables for the transmission time and the cost are linked to each other. They are designated with Kos and t_Ub.

Table 2

AND ↘

Kos / t_Ub	VL	LOW	MED	HIGH	VH
VL	VH	VH	VH	HIGH	MED
LOW	VH	HIGH	HIGH	MED	LOW
MED	VH	HIGH	MED	LOW	VL
HIGH	HIGH	MED	LOW	LOW	VL
VH	MED	LOW	VL	VL	VL

Capacity and transmission time were, for example, not compared with each other, because firstly the cost of a higher evaluation than the two other variables was measured and secondly when establishing the price-performance ratio it is sensible to ignore the cost, something which would be more likely to happen when linking capacity and transmission time. In order to obtain straightforward and reconstructible control bases for example, rules in which in the premisses more than two variables were linked to each other were left out.

In the control base for the delay rules, V_R in Figure 2, the linguistic variables for the delay time tV and for the alteration of the delay dtV for the intermediate variables Time, designated with t in Figure 2, are linked. As before, they consist of 25 rules, each term of the one input variable being linked to each term of the other input variable with the aid of the AND-operator. Since this control base is two dimensional, unlike the other three control bases, it can be represented as a whole in Table 3:

Table 3

AND

tV / dtV	VL	LOW	MED	HIGH	VH
NM	VH	VH	HIGH	HIGH	MED
N	VH	VH	HIGH	MED	LOW
ZERO	VH	HIGH	MED	LOW	VL
P	HIGH	MED	LOW	VL	VL
PM	MED	LOW	LOW	VL	VL

The control base for the safety rules, designated with S_R in Figure 2, is more extensive than the other two control bases. It preferably consists of six groups of rules. In this connection, the first three groups consist of simple rules of the form:

If Variable_a = Term_1, then Variable_b = Term_2.

In which case to form Variable_a in each group, in each case "connection safety", designated with VSAF, "node safety", designated with NSAF and "packet safety", designated with PSAF can be used. Variable_b is always the "safety". As a result of these rules, 15 in total, the control area of a linear controller is produced. These control sets are represented in tables 4a, b and c.

Table 4

a)

VSAF	SAF
VL	VL
LOW	VL
MED	MED
HIGH	HIGH
VH	VH

b)

NSAF	SAF
VL	VL
LOW	VL
MED	MED
HIGH	HIGH
VH	VH

c)

PSAF	SAF
VL	VL
LOW	VL
MED	VH
HIGH	HIGH
VH	MED

In the remaining three control groups, two of the input variables are preferably linked to each other. This likewise happens with the aid of an AND-operator. In this connection, however, preferably not all possibilities are covered in the control matrix; only at the edges, i.e. in the regions in which one of the two variables which are considered takes on extreme values, are rules formulated. In this way the control area is steeper at the edges and remains substantially linear in the centre. This subject matter is represented in Table 5, in which case the connection safety is designated with VS and the node safety is designated with termed KS.

Table 5

AND

KS / VS	VL	LOW	MED	HIGH	VH
VL	VL	VL	VL	VL	LOW
LOW	VL	VL			LOW
MED	VL				MED
HIGH	VL			HIGH	HIGH
VH	LOW	LOW	MED	HIGH	VH

The two further control groups for connection safety and packet safety, or node safety and packet safety are preferably set up in an analogous manner.

Finally, the main rules, designated with H_R in Figure 2, are a particularly important control base. They are particularly important, because here the intermediate variables are linked to form the temporary output variable Weight WEIG. In this connection, it should be noted that the intermediate variables are constructed from 5 terms, from "VL", ... "VH"; for reasons of accuracy, however, the linguistic variable Weight consists of seven terms "VL", ... "VVH".

Like the safety rules S_R, the main rules H_R can also be divided into six groups of rules. The first three groups preferably consist of rules which are equally as simple as the first three groups of the safety rules S_R. Here, from each intermediate variables, such as performance, time and safety, designated with POW, t and SAF in Figure 2, the target variable Weight, designated with WEIG in Figure 2, is reproduced directly.

Because the highest significance for the routing decision is attributed to the variables Time, in these three groups the possibility of allocating weights to the rules is used. For example, the rules which reproduce the variable Time on the variable Weight are weighted with 150%, while the other two groups of simple rules are weighted only with 50%. Furthermore, it should be noted in this case that these are only examples, so that other weightings, or even no weightings at all, can be provided by the specialist without impairing the invention. This subject matter is represented in tables 6a to 6c.

Table 6

a)

POW 50%	WEIG
VL	VVL
LOW	VL
MED	MED
HIGH	VH
VH	VVH

b)

t 150%	WEIG
VL	VVL
LOW	VL
MED	MED
HIGH	VH
VH	VVH

c)

SAF	WEIG
VL	VVL
LOW	VL
MED	VL
HIGH	VH
VH	VVH

In the remaining three control groups, as in the case of the safety rules, in each case two of the intermediate variables are linked with AND, in which case, for example, the control matrices are also only filled at the edges. First of all, for example, the rules in which the safety SAF is linked to the time t, as represented in table 7.

Table 7

t / SAF	VL	LOW	MED	HIGH	VH
VL	VVL	VVL	VVL	VL	VL
LOW	VVL	VVL			LOW
MED	VVL				HIGH
HIGH	VL			VVH	VVH
VH	VL	LOW	HIGH	VVH	VVH

AND ↘

At the rules which link the performance POW to the (time) t, it is to be recognised that the variables "Performance" in comparison with the variables "Time" are allocated a lesser significance. This means a poorly evaluated performance is not seen so seriously as a poor evaluation of the time. This subject matter is represented in table 8.

Table 8

t / POW	VL	LOW	MED	HIGH	VH
VL	VVL	VL	VL	LOW	MED
LOW	VVL	LOW			HIGH
MED	VVL				VVH
HIGH	LOW			HIGH	VVH
VH	LOW	MED	HIGH	VVH	VVH

AND ↘

Likewise, at the rules which link the variable "Performance" to the variable "Safety", it can be recognised that a high safety of the connection is considered more important than a good performance, because what use is such a good connection if a large portion of the packet is nevertheless lost. This subject matter or regulating set is represented in table 9.

Table 9

	SAF / POW	VL	LOW	MED	HIGH	VH
	VL	VVL	VVL	LOW	MED	HIGH
AND	LOW	VVL	VVL			HIGH
↘	MED	VL				VH
	HIGH	VL			VVH	VVH
	VH	VL	LOW	MED	VVH	VVH

As a result of the structure of the six control groups, in the centre of the interval the response of the fuzzy evaluation system is determined by the three control groups which were described first, while by the last three control groups, the control area is shaped more steeply towards the edges. This means that the system there reacts more sensitively to alterations of the intermediate variables.

CLAIMS

1. A method for selecting a communications connection between two nodes of a multinode network from a plurality of possible such communication connections, comprising the steps of:

for each communication connection evaluating at least two parameters which are a measure of the performance of the communications connection; and

selecting a communications connection from the plurality of such connections on the basis of the weighted combination of the at least two parameters of said plurality of connections.

2. A method as claimed in claim 1, wherein fuzzy logic is used to combine the at least two parameters and the communication connection is evaluated in accordance with the results of the combination.

3. A method as claimed in claim 1 or 2, wherein the parameters are formed from at least two separate measured values.

4. A method as claimed in claim 3, wherein fuzzy logic is used to form the parameter from the measured variables.

5. Method for evaluating at least two multi-part communications connections in a multi-node network, having the following features:

a) at least two evaluation categories for evaluating a communications connection are predetermined;

b) for a respective communications connection, at least one respective measured value is detected to form each predetermined evaluation category, which measured value describes the connection with regard to the respective evaluation category;

c) for the respective communications connection, an evaluation measure is determined by evaluating the associated measured values, at least with regard to the

fulfilment of the respective evaluation category, in the form of degrees of fulfilment and all degrees of fulfilment are linked to each other in such a way that the communications connection which has higher degrees of fulfilment with regard to the evaluation categories receives an optimal evaluation measure.

6. Method according to claim 5, in which method at least in each case as evaluation category, the performance of the respective communications connection and/or the time response of the respective communications connection and/or the safety of the respective communications connection is predetermined.

7. Method according to claim 3, 4 or 6, in which at least in each case the following are detected as measured values for:

Performance:	transmission capacity, transmission cost, transmission time;
Time response:	delay time between two nodes, alteration over time of the delay time between two nodes;
Safety:	connection safety, node safety, packet safety.

8. Method according to one of the claims 6 or 7, in which method the measured values are processed by means of fuzzy logic, by being treated as linguistic variables whose degrees of fulfilment are determined with the aid of association functions, at least one fuzzy regulating set being used for each of the evaluation categories.

9. Method according to claim 8, in which method the evaluation measure for the respective communications connection is formed by twice using fuzzy logic, by processing the degrees of fulfilment for the individual evaluation categories by means of fuzzy logic, in which case they are treated as linguistic variables which are evaluated with the aid

of at least one main fuzzy regulating set.

10. Method according to one of the claims 8 or 9, in which method at least in each case regulating sets are used, which link the following variables to each other:

- cost of the communications connection to its transmission capacity;
- transmission time to the cost of the communications connection;
- delay time between two nodes to the alteration over time of the delay time between two nodes;
- connection safety of the communications connection to its packet safety.

11. Method according to one of the claims 9 or 10, in which method at least two regulating sets are used as a main fuzzy regulating set, which regulating sets link the following variables to each other:

- time response of the communications connection to its safety;
- time response of the communications connection to its performance;
- performance of the communications connection to its safety.

12. Method according to one of the preceding claims, in which method potential communications connections are evaluated and the potential communications connection which receives the optimal evaluation measure is selected for the setting up of a real connection.

13. Communications arrangement for implementing the method according to one of the preceding claims, in which arrangement the communication nodes and partial communication sections between the communication nodes are arranged in such a way that two communication subscribers can be connected to each other by way of at least two communications connections.

14. Communications arrangement according to claim 13, in which arrangement the method of the invention is carried out on each communication node.

15. A method for evaluating at least two multipart communications connections in a multinode network substantially as herein described with reference to the accompanying drawings.

16. A communications arrangement substantially as herein described, with reference to the accompanying drawings.

The Patent Office

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Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): H4K (KTK, KTM, KPT, KMR & KMG)

Int Cl (Ed.6): H04Q (3/00)

Other: Online : WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	EP 0674459 A2	AT & T (page 2 lines 38-54 and page 3 lines 2-7, 30-33 & 43-56)	1,3,5,6 and 12
X	EP 0372270 A2	NIPPON (page 13 lines 6-9 & 30-35, page 14 lines 22-36 and page 17 lines 25-28)	1,3,5,6 and 12
X	WO 94/28683 A1	BRITISH TELECOM (page 5 line 30 to page 6 line 12 and page 8 line 33 to page 10 line3)	1,3,5,6 and 12
X	WO 92/16066 A1	STRATACOM (claims 1 and 2)	1,3,5,6 and 12
X	US 5163042	TOSHIBA (column 2 lines 36-60 and column 4 lines 39-43 & 55-64)	1,3,5,6 and 12

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
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